WBS	Task Name
8	**US CMS Silicon Tracker Proje**

Notes

The US CMS Silicon Tracker project, as described in this project file and WBS dictionary, was redefined in early 2000 after the CMS collaboration made the decision in late 1999 to replace the MSGC tracker with silicon microstrips. This decision precipitated a major reorganization of the CMS tracker group into four consortia including a USA consortium based at FNAL. The new tracker is described at the following web site: http://d.home.cern.ch/d/duccio/www/layout/lay.html

The USA consortium was given the responsibility for production of all of the modules for the tracker outer barrel (TOB). (Note that the "USA Consortium" is synonymous with the "US CMS Silicon Tracker Group" in the text that follows.) The total number of installed modules in the TOB will be 5928. In addition there is anticipated production of 10% spare modules. Hence the total number of TOB modules to be produced is ~6600. The module design is extremely simple, requiring a minimum number of parts. All modules are single-sided. Completed modules are then installed in a drawer-like structure called a rod. The rods each hold 6 single-sided modules for layers of the tracker with an axial-only view. Stereo layers of the tracker are obtained by mounting single-sided layers back-to-back resulting in 12 modules installed in a single rod. The rods not only support the modules mechanically, but also contain the cooling pipes, optical hybrids, and cables that are required to operate them. Once completed, fully instrumented rods are burned in and then shipped to CERN for installation in the TOB wheel support system. The modules, rods, and supports are described at the following web site: http://cms-ultmb.web.cern.ch/CMS_TMB/barrel_silicon/outer_barrel_silicon.html

The US CMS Silicon Tracker Project is responsible for production of all modules for the TOB. This includes module assembly, wirebonding, testing, installation into rods, burn-in, and transportation to CERN. These tasks are described in more detail under more specific task headings below. Module assembly is planned to take place using an automated, pick-and-place gantry system as developed at CERN and based upon a commercially available machine manufactured in the USA. In order to carry out the production of the TOB modules, the US CMS SIlicon tracker group must prepare all of the production and testing equipment. These include installation and preparation of the gantry system for module assembly, fabrication of fixtures for holding modules durring wirebonding, fabrication and assembly of transportation and testing boxes to protect modules during production and testing, purchase and assembly of probe stands and test stands for spot checking of sensors and hybrids and for module testing, and a relatively large volume cold box and associated test stand for burn-in of modules on rods. Finally, it will be the responsibility of the US CMS Silicon tracker group to design boxes for transport and to transport the completed rods to CERN.

In addition to the

8.1	**Components**

Notes

Note that all of the components used in the TOB modules and rod assemblies as well as the TIB support cylinders will be supplied to the US CMS Silicon tracker group by the other 3

WBS Task Name

"Components" continued

Notes

consortia in the project. As a result, the cost to the project for components is limited to clean room materials.

8.1.1 Miscellaneous clean room materials

Notes

For the duration of the project, a variety of disposable and otherwise perishable clean room materials and tools will have to be obtained. These include lab coats, booties, hair nets, face masks, gloves, tweezers, tape, epoxies, and so forth. The cost assigned is based upon the Run 2 silicon project's monthly expenditures for these items, scaled down to match the smaller total number of technicians and clean room space of the CMS tracker project.

During peak Run 2a clean room usage (FY00-01) SiDet budgeted for clean room materials as follows:

Disposables	30k/yr
Common Production materials (wirebonder wire, C-Fiber)	15k/yr
Misc. stockroom and other technician support	15k/yr

From this we obtain approximately $5k/mo. for cleanroom materials for all of SiDet. The CMS silicon tracker project will require a peak of roughly 17 technicians and will average less than 11 technicians over its expected 30 month duration. During peak Run 2a silicon production, SiDet clean rooms were occupied by roughly 35 technicians. We expect to use clean room materials in proportion to the number of technicians active in the project. We have therefore assigned a cost of 2k$ per month to this item with 21% contingency.

8.2 Equipment, Design, & Machini

Notes

A list of the new equipment needed by this project follows:

ITEM	QTY
Automated pick-and-place module assembly systems	2
Fixtures and Material Handling system for 8090 wirebonder	1
PC based test stands for electronic tests and burn-in of modules	6
Full DAQ test stands for extensive electronic tests of modules	3
Cooled burn-in system	1
Boxes	
Dry boxes for silicon and module storage	35
Test boxes for modules	200
Transportation and storage boxes for rods	6
Probe station for silicon	1
Logic analyzer	1

The project will also require technical support for the setup and maintenance of this equipment. Finally, the project will need fairly continuous engineering, design, and machining support for the production and modification of small fixtures (e.g. for wirebonding), and for the

WBS Task Name

"Equipment, Design, & Machining" continued

Notes

various boxes used in the project.

8.2.1 Machined parts

Notes

Machined parts are predominantly those pieces required for production fixturing. These include fixturing for wirebonding and the vacuum chucks used by the gantry system for module assembly. We also have to anticipate the need for repair or replacement of parts for module assembly equipment. It has been our experience in Run 2a that a fairly continuous level of machinist, engineer, designer, and technician support is required for various small jobs in these projects. We have therefore assumed continuous engineering, design, and machining support at the 0.5 FTE level each for the duration of this project.

8.2.2 Mechanical Assembly Equipm

Notes

This category corresponds to the equipment used in the actual fabrication of deliverables. It also includes the cooling stand used for the final long-term testing (burn-in) of modules on rods.

8.2.2.1 Automation equipment

Notes

The cost of automation equipment is dominated by the cost of the pick-and-place gantry machines. These are produced by Aerotech in Pittsburgh. We have been quoted a price of ~60k$ per machine and 12 weeks delivery lead time. In addition to the gantry, there are a large number of ancillary components required. Many of these are to be produced by the European Consortia. Some of the parts will be machined in the US as mentioned above. The remaining components need to be purchased. The items and their costs are listed below. Note that we intend to commission two such machines. The quantities assumed in the list reflect the costs per machine:

We list here the Gantry system components as obtained from the Gantry group. Note that many prices are based upon quotations received in Europe. Aerotech numbers are based upon a quotation we received directly from the vendor.

1. AGS10000 Linear Motor Gantry	$ 55,571	Aerotech
2. Four axis expansion card	1,980	Aerotech
3. Handwheel assembly with integral cable	920	Aerotech
4. Breakout module	415	Aerotech
5. Interconnect cables(3)	390	Aerotech
6. Vibrationless table	2,400	Mitutoyo
7. Camera system	4,800	Marcel Aubert
8. Monitor	500	Sony
9. Standard PC	2,400	(400CHF = CERN Standard)
10. IEEE interface	500	Matrox? or LabVIEW?
11. Vacuum pieces	4,800	FESTO
12. Vacuum valves control box	3,900	Brussels group
13. Gantry tools	-----	We machine at FNAL using CERN

WBS	Task Name

"Automation equipment" continued

Notes

Designs. These are already included in the machined parts task above.

14. Base plates	2,100	CERN
15. Interface software	1,000	
16. Epoxy dispenser	1,500	ESF
17. Vacuum pump	200	
18. UPS system 1500 V	600	
	83,976	

Several of these items have some uncertainty and it is not clear at this time whether we will need racks or a crate for some of the controllers. We therefore take the base cost per system to be 85k$ and assign 30% contingency.

8.2.2.2 Automation equipment(FNAL Base)

Notes

See above description of this equipment.

8.2.2.3 Equipment setup

Notes

The following is a list of systems that need to be setup for this project:

1) Gantry robotic module production systems

We will commision the first in early 2001. The second will go into operation in the summer of 2001. This system is rather sophisticated and represents methods of silicon module construction which are new to FNAL. We will need a very competent technician and perhaps a small level of engineering support for this over a period of roughly 6 months.

2) DAQ and pc test stands, cooling system and interlocks for burn-in station::

The DAQ and even the pc test stands require some time to get up and running, and completely understood. In the past this has been done by physicists and this is going to be the case again here. However, we do have to expect the possible need of bringing an expert to FNAL from Europe to help us. For subsequent system setups we expect to have enough expertise within our own group to do this ourselves. We include the cost of 2 round-trips from Europe.

3) Fixtures for the assembly of TIB support cylinders

This task is dealt with separately below, in the section on TIB support cylinders.

For items 1) and 3) we do not yet know exactly what will be involved. For item 1) in particular, we have no prior experience. For item 2) we have had some experience but these systems are very specific to the modules and electronics involved and we will have to operate at lower temperature than was the case in Run 2. We assign 0.5 FTE Technician Specialist, 1.0 FTE technician, and 0.25 FTE Engineer to the task of setting up these items. Since we have a fair amount of uncertainty about some of these systems, we have assigned 100% contingency to this task.

WBS	Task Name

"Equipment setup" continued

Notes

For these items we also allow for the possibility of paying for members from the other consortia to come to FNAL to help us setup equipment.

8.2.2.4 Equipment maintenance

Notes

The following systems are used extensively in this project

1) Two gantry pick-and-place systems
2) One or possibly two K&S 8090 wirebonders
3) One OGP optical inspection station
4) One 1 m B&S CMM
5) One 3 m B&S CMM 6) 3 DAQ test stands
7) 6 pc test stands
8) One cooling stand

We expect that the OGP, CMMs, and wirebonders, which are part of the SiDet equipment base, will be maintained by SiDet as was the case for the Run 2 silicon projects. The remaining systems will be maintained by this project. Note that the test stands will likely be maintained by physicists (as was the case in past projects). The cooling stand and gantry systems will however need some expert care. For the duration of the project we assign 0.25 FTE technician (e.g. Ray Safarik) and 0.1 FTE engineer to this task.

8.2.3 Wirebonding Machinery

Notes

SiDet has two high speed K&S 8090 wirebonders. We have conservatively calculated that our production pace of
~12 modules per day will require approximately one shift per day at most on one of these machines. Our contingency model however assumes that this pace may need to be doubled for up to 6 months to recover from possible schedule delays resulting from possible delays in components arriving at FNAL. At peak, in the worst case, we do not anticipate that we will require more wirebonding capacity than is currently available at SiDet. In addition, we do not assume more than 8 hours per day of operation whereas Run 2 wirebonding was often carried out for 12 hours per day, and 6 days per week. Nevertheless, we have to consider what may occur if Run 2b projects, CMS pixels and BTeV pixels, all require wirebonding capacity at the same time. In this situation, it is not likely that CMS silicon can assume full time use of more than one machine.

Note that in our calculations we have assumed that modules are mounted to fixtures and bonded more or less the same way that modules were done in Run 2a CDF ISL silicon project. We believe that it may be possible to greatly increase the throughput of the existing machines by taking more advantage of their automated capabilities. In addition, the machines are designed to work with material handling systems (MHS) that feed parts automatically to the bonding area. These MHS cost roughly 50k$. We have thus attached 66k$ to this task to cover the cost of one MHS and the fixturing needed to hold the modules. It may then be possible that one machine, with MHS, can handle 20-25 modules per shift. However, we do

WBS	Task Name

"Wirebonding Machinery" continued

Notes

not know at this time that such a scheme is plausible and there is a chance that even if it does work, the improvement is still not adequate to cover our most extreme needs. To make up for a possible shortfall, we added enough contingency to be able to purchase an additional K&S 8090 wirebonder. This machine has a cost of 250k$.

8.2.4 Burn-in Cooling system with interlocl

Notes

The modules are intended to be operated at -10 C. The burn-in system will therefore need to operate many modules (up to 72 on 12 rods) for many days at these low temperatures. The system will also need to have many safety features and interlocks to protect the large number of modules from damage due to cooling system failure or power outages etc. Hence, the burn-in system will have to be designed and built well.

Based upon what was done for CDF and D0 module burn-in at SiDet for the Run 2a projects, we believe that the cost of the CMS burn-in stand need not be too substantial. At this time we do not have a mature design for this stand. There are two concepts being considered. One is to build a custom box or rack system with integrated cables, interlocks, and cooling. The box would hold 12 rods. Such a system would require some engineering and design resources. In some sense, it is equivalent to a small scale experimental detector with 37k channels that has to be operated for several days continuously. The main difficulty would be in controlling the temperature. A second possibility could be to purchase a walk-in freezer such as is used at supermarkets for meat storage. We would still need a chiller, but the insulation of the system would be guaranteed, and gas flow would insure dryness. We would not have to design a complicated, well insulated box in this case.

The cost of a small walk-in freezer is roughly 5k$ (we checked with Dominick's Finer Foods). The cost of a small, low temp chiller with air separator, recirculating valves, and instrumentation is 10k$ (CDF Run 2a cost). A rack to hold the rods could be quite simple, and would not cost more than 2k$ (D0 Run 2a - see below). The interlock system would cost under 20K$, based on CDF Run 2. Note that CDF did not use a PLC, but set up a simple pc based system to monitor the burn-in system and to interlock it. This is described at the following CDF internal website
http://www-cdf.fnal.gov/internal/people/links/StevenBlusk/my.html.
In addition we would need a fair amount of cabling and there would be construction and installation costs. We estimate 1.0 FTE technician and 0.5 FTE designer for 3 months.

The CDF and DZero burn-in systems costs are listed below for comparison

The DZero Burnin test setup: The cost for one rack (16 modules) is as follows.

chiller	(provided by SiDet)
rack	(obtained secondhand)
rails	$ 70 stockroom item
plexiglass (siding), aluminum (top,bottom) , plywood (plates)	~ $100
aluminum plates for cooling	~ $500 machining mainly
tubing, polyethilene	$ 15 stockroom item
tubing, flexible, vinil	

WBS	Task Name
8.2.5	**Boxes**

Notes

The sensors, modules, and fully assembled rods are vulnerable in many ways. As a result, they require a storage area whcih is dry and at constant temperature, and which protects them from electrostatic damage or mechanical shocks.

Sensors can be stored in the Lab D dry nittrogen storage area. Additional storage boxes will be required since the Lab D storage is also to be used by CDF and D0 for Run 2b silicon. Modules, once assembled, are mounted in protective boxes from which they are removed rarely, such as for wirebonding. Tests can be performed with the modules inside these 'test' boxes. Modules can then be stored in converted refrigerators as was the case for CDF ISL.

When modules are complete, they will be installed in rods. The rods are to be stored in the boxes that will be used to transport them to CERN. These transportation boxes will be designed to carry up to 30 rods and to occupy an economy seat of an airplane. The majority of rods hold 6 modules but a substantial fraction have 12. At 30 rods per box, we will need to ship 25 such box-loads to CERN. We will construct 6 such transport boxes to allow for the possibility of loading some while others are in transit.

8.2.5.1 Storage

Notes

Typical dry storage boxes now at SiDet cost $1k. These are not large volume boxes. We anticipate a need for as many as 35 more of these boxes to store large quantities of silicon.

8.2.5.2 Transportation boxes

Notes

The boxes used to transport assembled rods to CERN will be mainly designed to keep the modules dry and electrostatically protected while also protecting them from bumps. In discussions with United Airlines, we were advised not to send our assembled rods as cargo. The recommendation was that we should build a carry on box for them. We have now a conceptual design for a box that would hold up to 30 rods or so (180-250 modules). The box could be proportioned to be stored in the overhead bin of some larger airplanes. Alternatively, it could be designed to mount to an adapter that would position it safely in a standard economy class seat. The box would and seat adapter would be rather straightforward to design. They would however require some additional features to allow monitoring of accelerations and for humidity and temperature control. They would also have to be fairly light weight. It is our belief that these boxes would not cost more than a few thousand dollars each. However, since they are at a very preliminary stage of conceptual design, we have assigned a very conservative cost of 5k$ each.

8.2.5.3 Test Boxes

Notes

Test boxes are designed to hold individual modules. We have made many dozens of these boxes for the Run 2a projects. Typically these boxes cost no more than $250 each. We are assuming that we will need 200 such boxes as a result of our large expected throughput of modules in this project. The test boxes themselves, with modules inside them, can be stored in modified refrigerators as was the case in Run 2a for the CDF ISL project.

WBS	Task Name
8.2.6	**Instrumentation**

Notes

This group of tasks deals with the instrumentation that will be required for this project. This includes the test stands for electronic tests and burn-in, equipment for a probe station for silicon, and some miscellaneous instrumentation such as a logic analyzer which will very likely be required.

8.2.6.1 Electronic Test

Notes

Based upon our Run2a experience, we estimate that quite a few module and hybrid test stands will be required in this project. The test stands are of two main types. First, there is the full DAQ stand, using all of the components that will be used in the experiment. These stands allow complete testing of modules in the operational conditions that will exist during the operation of the final installed detector. Unfortunately, full DAQ test stands are expensive. The second type of test stand is referred to as a pc-based test stand. These stands use simple components, techniques, and software to perform basic tests on modules and hybrids. The tests fall short of checking exactly how the modules will perform in every detail. They do however allow enough information to be gathered to tell us if any damage whatsoever has occured duing module construction.

The two types of test stands are therefore used as follows. The majority of testing during production is performed with the pc-based test stand. All modules can undergo a test on a full DAQ system for final checkout. It may also be adequate to test only a fraction of modules with the full DAQ stand. The pc-based test stands are also ideal for testing at institutions other than FNAL where, for instance, radiation studies are underway. However, it may be preferrable to have a full DAQ stand at the module repair facility since some of the modules which require repair could do so as a result of more subtle problems that only turn up in full DAQ testing. Also, once modules are installed on rods, they should only be tested with a full DAQ stand. Since burn-in occurs on the rods, this means that the test stand used for our burn-in system is a full DAQ stand.

We estimate that we will need 3 full DAQ test stands and 6 pc-based test stands. A DAQ stand will be requied at the repair center (UC Santa Barbara) . Two will be needed at FNAL: one for burn-in and another for full testing of completed modules. The pc-based test stands will be needed at each of the institutes performing QA assurance, at the repair center, and at FNAL. At FNAL we will need one in the wirebonding area for quick testing to assure bonding is not causing damage. We will also need one in the area where modules are installed on rods to assure no damage occurs in this assembly step. The cost and status for test stand items (as of August 2000) is listed below

1. PC based test stand as prototyped by the Lyon group: see for instance
http://lyopc134.in2p3.fr:8090/~mirabito/daqrepport.html or
http://lyopc134.in2p3.fr:8090/~mirabito/daqrepport.ps

PC with PCI and ISA slots	$2000
APV control cards (TTCvx or TTCvi)	$1000
Additional cards for added functionality	$1500
S/W: Drivers, Oracle DB available	no cost

WBS	Task Name

"Electronic Test" continued

Notes

8.2.6.2 Probe-station

Notes

All sensors will be tested at the manufacturer. In addition, they will be retested very thoroughly by the sensor test groups in Europe before shipping to FNAL. However, in order to assure that no damage is occuring in transport, a small percentage of each shipment of sensors will be probed in the US at Kansas State University. Some equipment must be purchased in order to match the existing probe station at Kansas State University to the setup used by the sensor group. We have allocated 55k$ for this as a result of the following costs.

EQUIPMENT

LabView, GPIB interface & cables	$4,100
LCR meter -HP4284A	13,500
Electrometer - Keithley 237	8,000
Data Acquisition/Switch Unit Agilent 34970A	1,300
Automatic probe station	(60k - provided by KSU)
Microscope Mitutoyo manual focus,FS-60(with video adapter)	8,600
Probe card	1,000
Dry box	1,500

EQUIPMENT SUBTOTAL 38,000

CONSTRUCTED EQUIPMENT

Engineering support	2,700

CONSTRUCTED EQUIPMENT SUBTOTAL 2,700

MATERIALS, SERVICES, & SUPPLIES

Electronics components	2,400
Clean room supply	1,000
Nitrogen	2,500
Miscellaneous supplies	1,000
Sensor Shipping and insurance (50*120$)	6,000

M&S SUBTOTAL 12,900

8.2.6.3 Miscellaneous instrumentation

Notes

We expect that we will need a good logic analyser which costs of order 50k$. We could easily find that we have not included all of the instrumentation we will need for our tests and burn-in. Hence we have added 100% contingency to this item to cover these items. This item is in some sense an explicit contingency item. However, it has been our experience in 2 generations of silicon detector projects that some additional money is always needed for unanticipated instrumentation costs.

WBS	Task Name

8.3 Sensor Probing

Notes

All sensors will be extensively probed before they are shipped to FNAL. Probing will be done by the manufacturer and also at the sensor test centers in Europe. We will check a small percentage of each shipment to verify there is no damage occuring in transit. This work will be done at Kansas State University by technicians and students

8.3.1 Probe pre-production sensors

Notes

In this period the probe station will be setup and procedures refined.

8.3.2 Sampled Probing of Production Sens

Notes

As discussed earlier, all sensors will be extensively probed before they are shipped to FNAL. We will check a small percentage of each shipment to verify there is no damage occuring in transit. This work will be done at Kansas State University by a technician and students.

8.4 Modules

Notes

The modules will be built in three phases:

1. Pre-production of 80 modules

This corresponds to a very slow production rate in which methods and procedures are developed and quality is expected to continually improve.

2. Ramp-up of 600 modules

This period corresponds to the finalization of procedures and methods. Toward the end of this period the focus will be on reaching and maintaining our desired throughput of high quality production modules.

3. Production of 6000 modules

For this period the procedures will not change and the emphasis will be on steady throughput with uniform high quality. As a safeguard against possible delays that will need to be made up, we have included enough manpower and equipment contingency to allow for a doubling of peak production rates. In addition, we are prepared to setup a second production site for greater throughput, or to avoid conflict over capacity at SiDet.

Note that a single gantry machine can achieve 24 module production per day in principle. Since this is the highest rate we can imagine ever needing to achieve, it appears that we do not need the capacity of the second machine so that it is really only a backup. However, there is a possibility that both machines do become necessary for production as per the following scenario. There is a fairly high probability that there will be a significant Run 2b silicon effort for CDF and D0 at SiDet which overlaps the CMS tracker project. In particular, it looks like there will be overlap starting in early 2003. The capacity of SiDet is probably adequate for all of these projects in most respects. I.e. there could easily be adequate space and CMMs. There may be serious competition for wirebonding time however. In any case, if there is a serious capacity shortage at SiDet, the CMS tracker project could move a gantry to a collaborating institution where a second full production line

WBS	Task Name

"Modules" continued

Notes

could be started. The most likely place would be UC Santa Barbara where there is substantial siilicon experience (CLEO III and BaBar) and good space, and technical and machining support. Since UCSB would already be doing repair work, the transition to a production site would mainly require the transfer of the gantry machine, and purchase of a high speed wirebonder. The cost of this wirebonder has been included in the contingency for the wirebonding equipment task (UCSB may be able to absorb a substantial fraction of the cost). There would also be a slight increase in the technical staff but most of the technical and engineering support at UCSB would be contributed at no cost to the CMS project. It would also not be necessary to carry out burn-in at UCSB. Modules would be tested at UCSB (there would already be a full DAQ and a pc test stand there for repairs) and mounted into rods, then shipped back to FNAL for burn-in. In this scenario it may be necessary to suspend repair of modules until most production was complete.

8.4.1 Preproduction of 80 modules

Notes

Pre-production run of 80 TOB modules. The goal is for these modules to be high enough quality that they can be installed in the tracker if necessary. They represent roughly 1.5% of the total to be built. It is intended to build these modules with final components and methods to the greatest extent possible. It is probable that the final hybrid will not be available for them however.

8.4.1.1 Mechanical Assembly

Notes

Mechanical assembly of the 80 or so pre-production modules is assumed to be complete by June of 2001. The pace of production will be quite slow as we learn to use the gantry assembly stations and begin to exercise all of our production methods. The mechanical assembly will therefore require 0.5 FTE of a technician who's experience can be used to refine our procedures, assisted by a less experienced technician at 0.5 FTE. This work will be carried out with a physicist.

Based upon our experience with the CDF ISL, and the expectation that the gantry system should simplify the production, we believe that the manpower we have assigned to this task is extremely generous.

8.4.1.2 Wirebonding

Notes

We will be building pre-production modules at an average pace of a few modules per week. These modules are going to be much simpler to wirebond than ISL modules as seen by comparison of the modules characteristics:

ITEM	CDF ISL	CMS TOB
No. of Sides	2	1
Total no. of wires	3072	1024 or 1536

For CDF ISL Modules, it was possible to bond both sides of one module in under 1.5 hours. The CMS modules should require considerably less time (less than 45 minutes). We have

WBS Task Name

"Wirebonding" continued

Notes

assigned 0.2 FTE wirebonder technician to this task which is more than adequate by a large factor.

8.4.1.3 Inspection

Notes

We plan to inspect the modules after construction on the OGP system. For CDF ISL the inspection process takes about 30 minutes. We assume the CMS modules will take no longer than this. We have assigned 10% FTE technician to this task, accompanied by a physicist. Again, this is more than adequate for the small production rates required in the pre-production phase of this project.

8.4.1.4 Repair

Notes

Repair is expected to be predominantly removal of wirebonds on channels that have developed pin holes during production. We found that this required about 1 hour of work per ISL module. The CMS modules should have fewer such problems however, since they are single-sided and mechanical damage is therefore much less likely. Nevertheless, we assume roughly 1 hour per module for repair.

If more extensive repair work is required, the modules will be shipped to a separate repair site for more in-depth study and repair. We do not plan to have extensive repairs undertaken at the main production site as this would interfere with our goal of high throughput.

8.4.1.5 Testing, rod assembly & burn-i

Notes

Testing of modules is performed at several points in the production chain. The initial tests are brief and occur shortly after wirebonding to determine if damage is occuring in the bonding step and whether or not any rare pin holes have been created for which wirebonds need to be removed. After this step, a more extensive 'full' electronic test is performed to characterize the detailed performance of the module. Assuming the module passes these tests, it can be installed in a rod. The rods contain the cooling and cabling for the modules as well as the optical readout hybrids for communication with the DAQ. The rods will be installed in a burn-in cooling stand for 3 days of continuous operation and monitoring in more or less standard CMS operating conditions (less the beams of course). The modules are thus operated at low temperature, with continous triggering and clocking of data etc. There is also expected to be several thermal cycles to test the stress reaction of the modules to make sure that nothing goes wrong under typical experimental conditions. When all modules on a rod pass burn-in without a problem, the rod is ready to be shipped to CERN for installation. If a module in the rod has problems, it can be replaced individually with another module that has survived the burn-in process.

Module testing will be a shared responsibility of FNAL, UIC and KU.

8.4.1.5.1 Full electronic test (KU)

Notes

In the pre-production phase of the project, all testing will be done by physicists. This will carry on until the procedures are automated adequately for a technician to be able to perform

WBS **Task Name**

"Full electronic test (KU)" continued

Notes

all tests. The test results will always be reviewed by physicists to monitor quality.

8.4.1.5.2 **Full electronic test (FNAL)**

Notes

In the pre-production phase of the project, all testing will be done by physicists. This will carry on until the procedures are automated adequately for a technician to be able to perform all tests. The test results will always be reviewed by physicists to monitor quality.

8.4.1.5.3 **Full electronic test (UIC)**

Notes

In the pre-production phase of the project, all testing will be done by physicists. This will carry on until the procedures are automated adequately for a technician to be able to perform all tests. The test results will always be reviewed by physicists to monitor quality.

8.4.1.5.4 **Rod assembly**

Notes

Rods will arrive at FNAL already prepared for module installation. I.e the cables, cooling, and optical hybrids will all be attached and will have been tested. The mounting points will also all have been surveyed and tested. Hence, it is expected to be a rather straightforward process to install modules in the rods. We have assigned 20% technician time to this task due to the rather low rate of production in this period. This manpower allocation for this task is several factors more than what we expect to need at this stage.

8.4.1.5.5 **Burn-in (KU)**

Notes

As for the full electronic test, the burn-in during the pre-production period will be carried out by physicists until all procedures are established and automated at which time the work can be carried out by a technician supervised by a physicist part time. Note that once the modules are installed and the burn-in procedure begins, there is little that anyone needs to do until the 3 day burn-in period has ended. The exceptions to this all correspond to system failures such as a power cut or chiller break down which are relatively rare.

8.4.1.5.6 **Burn-in (FNAL)**

Notes

As for the full electronic test, the burn-in during the pre-production period will be carried out by physicists until all procedures are established and automated at which time the work can be carried out by a technician supervised by a physicist part time. Note that once the modules are installed and the burn-in procedure begins, there is little that anyone needs to do until the 3 day burn-in period has ended. The exceptions to this all correspond to system failures such as a power cut or chiller break down which are relatively rare.

8.4.1.5.7 **Burn-in (UIC)**

Notes

As for the full electronic test, the burn-in during the pre-production period will be carried out by physicists until all procedures are established and automated at which time the work can be carried out by a technician supervised by a physicist part time. Note that once the modules are installed and the burn-in procedure begins, there is little that anyone needs to do

WBS	Task Name

"Burn-in (UIC)" continued

Notes

until the 3 day burn-in period has ended. The exceptions to this all correspond to system failures such as a power cut or chiller break down which are relatively rare.

8.4.1.6 Documentation

Notes

The book keeping required for this project overall will be significant and merits its own task. For the pre-production phase it will be somewhat limited. For the ramp-up to full production, we will also try to get a sophisticated tracking and archival system into full operation so that it is ready for the full production period.

8.4.1.6.1 Assembly, Test, Ship/receive

Notes

There will not be a significant effort required for the documentation of these modules since there are so few of them. We may begin to use the standard CMS tracking software at this stage, which will require some assistance from a computer professional and physicist. However, for the moment, we assume that the main tracking software usage will not start until the ramp-up period since the actual information that is tracked will depend somewhat on what is learned in the pre-production stage.

SiTrk-001 Start delivery of pre-production modu

Notes

Traker level 3 milestone.

SiTrk-002 Start to deliver final frames to assem

Notes

Tracker level 3 milestone.
This milestone must be met by the frame group in order for TOB modules to start. There is however a fair amount of float in the schedule for this particular milestone.

SiTrk-003 Start delivery of production sensors t

Notes

Tracker level 3 milestone.
This milestone must be met by the sensor group.
This milestone essentially determines when we can begin manufacturing production modules. If this milestone is not met by the sensor group then the TOB project start of module production will be delayed. This does not mean that the project as a whole will be delayed.

SiTrk-004 Start delivery of FE electronics to Ga

Notes

Tracker Level 2 Milestone:

The final FE electronics hybrids will be needed in order to start serious production. This milestone needs to be monitored carefully. The project plan we have developed is designed to allow us to recover from substantial delays in the arrival of production components from CERN. In particular, there is enough float in the schedule, and we are preparing enough capacity to allow us to absorb a one year delay in the arrival of substantial component deliveries from Europe without altering the completion date of the project.

WBS	Task Name
SiTrk-005	**First Rod Support Ready**

Notes

Tracker Level 2 Milestone:

The rod supports need to be ready in order for us to install modules on rods. This milestone determines when the first such supports are to be available. The rod supports will first go to CERN for installation of cooling, cabling and mounting hardware. They are then delivered to FNAL for installation of modules, burn-in, and subsequent return shipment to CERN.

SiTrk-006 **50% delivery of final frames to assem**

Notes

Level 4 milestone

This milestone must be met by the frame group in order for TOB modules to start. There is however a fair amount of float in the schedule for this particular milestone.

SiTrk-007 **50% delivery of FE electronics to Gar**

Notes

Level 4 Milestone:

The final FE electronics hybrids will be needed in order to start serious production. This milestone needs to be monitored carefully. The project plan we have developed is designed to allow us to recover from substantial delays in the arrival of production components from CERN. In particular, there is enough float in the schedule, and we are preparing enough capacity to allow us to absorb a one year delay in the arrival of substantial component deliveries from Europe without altering the completion date of the project.

SiTrk-008 **50% delivery of production sensors t**

Notes

Level 4 milestone.

This milestone must be met by the sensor group.

This milestone essentially determines when we can begin manufacturing production modules. If this milestone is not met by the sensor group then the TOB project start of module production will be delayed. This does not mean that the project as a whole will be delayed.

SiTrk-009 **100% delivery of final frames to asse**

Notes

Level 4 milestone.

This milestone must be met by the frame group in order for TOB modules to start. There is however a fair amount of float in the schedule for this particular milestone.

SiTrk-010 **100% of delivery of production senso**

Notes

Level 4 milestone.

This milestone must be met by the sensor group.

This milestone essentially determines when we can begin manufacturing production modules. If this milestone is not met by the sensor group then the TOB project start of module production will be delayed. This does not mean that the project as a whole will be delayed.

WBS	Task Name
SiTrk-011	**100% delivery of FE electronics to Ga**

Notes

Tracker Level 2 Milestone:

The final FE electronics hybrids will be needed in order to start serious production. This milestone needs to be monitored carefully. The project plan we have developed is designed to allow us to recover from substantial delays in the arrival of production components from CERN. In particular, there is enough float in the schedule, and we are preparing enough capacity to allow us to absorb a one year delay in the arrival of substantial component deliveries from Europe without altering the completion date of the project.

8.4.2 Assembly of 600 modules: ram

Notes

This task represents the start of the true production period for this project. We have scheduled ~120 to assemble 600 modules. This averages out to only 5 modules per day. However, it is our intention to start at a rate below this level and ramp up to a rate which is considerably above this level. The main goal of this period is to refine and finalize all of our procedures and quality checks, documentation and shipping methods. We will also seek to attain, as early as possible, our target steady state production rate of 12 modules per day. By the end of this period, we will have achieved steady state production at this level. Furthermore, we will attempt for at least a short period, a rate of 24 modules per day.

Depending on the arrival of parts from the other consortia, we will do everything possible to complete this phase of the production as early as possible. There is a good chance, in the absence of delays of incoming parts, that we will complete this work in advance of the schedule shown.

8.4.2.1 Mechanical Assembly

Notes

All mechanical assembly will be done with the gantry machine. A single gantry machine can build 3 modules in roughly 1 hour, with most of the time devoted to preparation of materials. A single machine operating in 4 construction cycles can therefore reach our assembly rate target of 12 modules per day. The second machine therefore represents two types of contingency. First of all, the second gantry machine assures continuity in steady state production if one machine happens to go down. Second of all, it allows us to set up a second assembly site if necessary.

A single gantry machine operating at a few cycles per day is designed to be operated by a single technician. In this task we have allocated 1.5 FTE technician labor. This is more than what is needed but allows us to train several technicians as backup and to prepare for the operation of two machines.

8.4.2.2 Wirebonding

Notes

For wirebonding in this period, we expect to need no more than one machine and operator. We estimate, based upon the ISL project, that a single K&S 8090 wirebonder can easily wirebond as many as 16 CMS modules in one 8 hour shift, assuming continuous operation. In this 600 module ramp-up period, we will average 5 modules per day which corresponds to 0.5 FTE wirebond technician.

WBS	Task Name
8.4.2.3	**Inspection**

Notes

Inspection of completed modules on the OGP will be performed on a fraction of modules to verify that mechanical specifications are being met. The plan would be to inspect one of every 5 or 10 modules, corresponding to a particular day or several days worth of production. The time reqiured to write an inspect a module is not more than 30 minutes. We have therefore assigned 0.4 FTE technician to this task.

8.4.2.4 Repair (UCSB)

Notes

Repairs are expected to be of two classes. Simple repairs will correspond to the removal of wirebonds on bad channels. As discussed above, we expect this to be necessary less often than was the case for CDF ISL. For the latter, every module needed a small number of wirebonds removed. Typically less than one hour was devoted to this.

Some modules cannot be repaired in this manner. I.e. some more subtle problem may arise having to do with the hybrid such as bond damage or chip failures etc. These modules will be taken out of the main production line and sent to UCSB for in depth debugging and repair. The manpower for this effort at UCSB will be physicists, with some help from technicians or students.

8.4.2.5 Repair (FNAL)

Notes

As mentioned earlier, the ISL module repair was typically restricted to remove a wirebond or two and retest the module. We expect this to be the same for CMS modules. We expect even this type of repair could be much less frequently required than was true for ISL for two reasons, both of which stem from the fact that the CMS modules are single-sided. First of all, the majority of pin holes that occured in ISL modules stemmed from microscopic mechanical damage as a result of contact of one of the two active surfaces with fixtures during assembly or bonding. For single sided CMS modules, there is never a need for active surfaces to contact the fixtures. Secondly, the CMS modules are back-side biased and the electronics and strips can be held at ground. This means that the strip-to-implant voltage need never be very large. CDF ISL detectors on the other hand are split biased, so that much higher fields can exist across the oxide separating the implant from the metal strip. This can contribute to capacitor breakage.

FNAL will take responsibility for simple repairs.

We have assumed that the simple repairs done per module will require as much effort as was the case for ISL. This is pessimistic for the reasons given above. The manpower we have associated with this task is 0.25 FTE technician and 0.5 FTE physicist. (All repairs were done by a physicist for ISL).

8.4.2.6 Testing

Notes

Testing occurs in several points in production as described earlier. The same people will be used in some cases for several tests. For example, the persons involved in burn-in will be able to also do hybrid and module testing as discussed below. For the ramp up period of production, we expect all testing to be initially done by physicists to establish the procedures and automate them. Technicians will start to be trained in this period.
Testing and Burn-in will be the joint responsibility of FNAL, UIC and KU.

WBS	Task Name

8.4.2.6.1 **Full electronic test (KU)**

Notes

All arriving hybrids and completed modules will have a full electronic test performed. The work will be done by physicists but it is expected that a few technicians will start to be trained in this period.

8.4.2.6.2 **Full electronic test (FNAL)**

Notes

All arriving hybrids and completed modules will have a full electronic test performed. The work will be done by physicists but it is expected that a few technicians will start to be trained in this period.

8.4.2.6.3 **Full electronic test (UIC)**

Notes

All arriving hybrids and completed modules will have a full electronic test performed. The work will be done by physicists but it is expected that a few technicians will start to be trained in this period.

SiTrk-012 **First modules ready for installation**

Notes

Tracker L3 Milestone: This milestone is set by the tracker group to correspond to the date when the first modules that could be used in the final installation are complete.

8.4.2.6.4 **rod assembly**

Notes

The 600 modules to be built in the ramp-up to full production will be installed in 100 rods. The rods are designed to accept the modules quite simply. Actual installation of modules should therefore be quite simple and not require a lot of time. We have conservatively estimated 0.25 FTE of a technicians time for this. This should also be enough manpower to enable us to survey the module locations on the rod using a mid-size CMM (like the small B&S machine in Lab C). In principle the alignment is guaranteed by the placement of the mounting hardware on the rod. Ultimately it should not be necessary to survey all rods.

SiTrk-013 **First assembled Rod ready**

Notes

Tracker Level 2 Milestone.

8.4.2.6.5 **Burn-in (KU)**

Notes

For burn-in of modules on rods, as discussed previously, there is little that can be done once the burn in procedure is initiated. Manpower is required to setup the burn-in, by installing a number of rods and running the burn-in programs and cooling systems and verifying interlockst etc. The system is then monitored at regular intervals for 3 days or so. We assign 0.25 FTE post-Doc or physist per institution to this work during the ramp-up period. The technician training time for this task is already covered under the full test task above.

8.4.2.6.6 **Burn-in (FNAL)**

Notes

For burn-in of modules on rods, as discussed previously, there is little that can be done once

WBS	Task Name

"Burn-in (FNAL)" continued

Notes

the burn in procedure is initiated. Manpower is required to setup the burn-in, by installing a number of rods and running the burn-in programs and cooling systems and verifying interlockst etc. The system is then monitored at regular intervals for 3 days or so. We assign 0.25 FTE physicist to this work during the ramp-up period. The technician training time for this task is already covered under the full test task above.

8.4.2.6.7 Burn-in (UIC)

Notes

For burn-in of modules on rods, as discussed previously, there is little that can be done once the burn in procedure is initiated. Manpower is required to setup the burn-in, by installing a number of rods and running the burn-in programs and cooling systems and verifying interlockst etc. The system is then monitored at regular intervals for 3 days or so. We assign 0.25 FTE post-Doc to this work during the ramp-up period. The technician training time for this task is already covered under the full test task above.

SiTrk-014 Rod ready for burn-in

Notes

Tracker Level 2 Milestone

8.4.2.7 Documentation

Notes

This task covers the documentation of all testing and the inventory tracking of all components and completed parts.

8.3.2.7.1 Assembly, Test, Ship/Receive

Notes

We intend to use the ramp-up period to establish all of the final documentation and archival procedures for the project. This entails installing and learning the tracking software for the project which will be chosen by the tracker group as a whole. The programs will track all components: sensors, frames, hybrids and rods. It will also track which components go into which modules and which modules go into which rods. A bar code system is now being developed for this. In addition, we will associate test data from hybrids and modules to the final module data files. We have assumed that we will need 0.5 FTE of computer professional, a technician or temp, and a physicist to setup this system.

8.4.3 Assembly of 6000 modules

Notes

This task corresponds to the vast majority of module production. All procedures, tests, quality assurance, documentation, etc. will have been finalized before starting this production phase. We also expect to be able to sustain a production rate of 12 modules per day with relative ease at the start of this phase of production, and to be able to double this rate if necessary.

8.4.3.1 Mechanical Assembly

Notes

For module assembly we assume a rate of 12 modules per day, with 1.5 FTE technicians, 1.5 FTE temps. and one physicist for this period. Given the capacity of the gantries, as discussed

WBS	Task Name

"Mechanical Assembly" continued

Notes

above, this labor force represents more than adequate coverage of this task. In fact, we have assigned enough manpower to be able to double this rate if necessary.

8.4.3.2 Wirebonding

Notes

As discussed earlier, a single K&S 8090 wirebonder and one FTE wirebond technician is adequate to maintain 12 modules per day production. We have allocated 2.0 FTE wirebonder technicians and 0.5 FTE physicist to this task, which is adequate to double the rate to 24 modules per day if necessary.

8.4.3.3 Inspection

Notes

As mentioned for inspection in the ramp up period, this task will be for spot checking of modules to verify mechanical specifications are being met in a given assembly batch. We want to constantly check that the gantries are not making subtle errors. It is not necessary to inspect all modules. We have therefore assigned only a small portion (0.5 FTE) of a technician to this task, and a physicist at 0.3 FTE.

8.4.3.4 Repair (UCSB)

Notes

Repairs are expected to be of two classes. Simple repairs will correspond to the removal of wirebonds on bad channels. As discussed above, we expect this to be necessary less often than was the case for CDF ISL. For the latter, every module needed a small number of wirebonds removed. Typically less than one hour per module was required.

Some modules cannot be repaired in this manner. I.e. some more subtle problem may arise having to do with the hybrid such as bond damage or chip failures etc. These modules will be taken out of the main production line and sent to UCSB for in depth debugging and repair. The manpower for this effort at UCSB will be physicists, with some help from technicians or students.

8.4.3.5 Repair (FNAL)

Notes

Repairs are expected to be of two classes. Simple repairs will correspond to the removal of wirebonds on bad channels. As discussed above, we expect this to be necessary less often than was the case for CDF ISL. For the latter, every module needed a small number of wirebonds removed. Typically less than one hour was devoted to this. For the CMS modules we expect far fewer repairs and the repairs should be more simple since the strip pitch is larger and the modules are single-sided. We assign 0.75 FTE technician and 0.5 FTE physicist/post-Doc to this task which corresponds to enough manpower to repair 40 ISL modules per week.

8.4.3.6 Testing

Notes

This task covers the testing of hybrids and modules, and burn-in of modules on rods.

WBS	Task Name
8.4.3.6.1	**Full electronic test (KU)**

Notes

Electronic testing in the final production stage will be performed by a team of 3-5 people. There will be 2 FTE techicians in the team and 2-3 physicists/post-Docs. The physicist will be on a production shift that lasts several weeks. The technicians will be trained to operate the test stands, and evaluate the results. In this way we hope to maintain continuity and uniformity without requiring the same small number of physicists to be responsible for 2 years of testing. The physicists will be responsible for evaluating results and assuring that procedures are followed and quality is maintained. Note that testing will be performed on hybrids when they arrive and on modules when they have been wirebonded. We estimate that two test stands will be required: one dedicated to hybrids and the other dedicated to modules. The former will be a pc-based test stand and the latter will be a full DAQ test stand. The same physicist can oversee both sets of tests. In addition to these tests, there will likely be a quick test performed immediately after wirebonding to check for damage at this step and to determine if wirebonds need to be removed. This stand will also be a pc based test stand and located in the wirebond area or in the general testing area. It will be operated by the technicians involved in hybrid testing and overseen by the physicist covering the wirebonding operations.

8.4.3.6.2 Full electronic test (FNAL)

Notes

Electronic testing in the final production stage will be performed by a team of 3-5 people. There will be 2.0 FTE techicians in the team and 2-3 physicists/post-Docs. The physicist will be on a production shift last several weeks. The technicians will be trained to operate the test stands, and evaluate the results. In this way we hope to maintain continuity and uniformity without requiring the same small number of physicists to be responsible for 2 years of testing. The physicists will be responsible for evaluating results and assuring that procedures are followed and quality is maintained. Note that testing will be performed on hybrids when they arrive and on modules when they have been wirebonded. We estimate that two test stands will be required: one dedicated to hybrids and the other dedicated to modules. The former will be a pc-based test stand and the latter will be a full DAQ test stand. The same physicist can oversee both sets of tests. In addition to these tests, there will likely be a quick test performed immediately after wirebonding to check for damage at this step and to determine if wirebonds need to be removed. This stand will also be a pc based test stand and located in the wirebond area or in the general testing area. It will be operated by the technicians involved in hybrid testing and overseen by the physicist covering the wirebonding operations.

8.4.3.6.3 Full electronic test (UIC)

Notes

Electronic testing in the final production stage will be performed by a team of 3-5 people. There will be 2 FTE techicians (including temps) in the team and 2-3 physicists/post-Docs. The physicist will be on a production shift last several weeks. The technicians will be trained to operate the test stands, and evaluate the results. In this way we hope to maintain continuity and uniformity without requiring the same small number of physicists to be responsible for 2 years of testing. The physicists will be responsible for evaluating results and assuring that procedures are followed and quality is maintained. Note that testing will be performed on hybrids when they arrive and on modules when they have been wirebonded.

WBS	Task Name

"Full electronic test (UIC)" continued

Notes

We estimate that two test stands will be required: one dedicated to hybrids and the other dedicated to modules. The former will be a pc-based test stand and the latter will be a full DAQ test stand. The same physicist can oversee both sets of tests. In addition to these tests, there will likely be a quick test performed immediately after wirebonding to check for damage at this step and to determine if wirebonds need to be removed. This stand will also be a pc based test stand and located in the wirebond area or in the general testing area. It will be operated by the technicians involved in hybrid testing and overseen by the physicist covering the wirebonding operations.

8.4.3.6.4 rod assembly (FNAL)

Notes

Rod assembly, as mentioned earlier, should be straightforward and not very time-consuming. Even at a peak production pace of 24 modules per day, we will need to assemble no more than 4 rods per day. This would require 0.5 FTE technician manpower. On average, we do not expect to need more than 0.25 FTE for this work. A physicist will be available at this step to run a quick test of the rod afterwards to make sure everything is fine. In addition, some sampling of rods (25 % or more) will be surveyed on the CMM to verify module locations are within specifications.

8.4.3.6.5 Burn-in (KU)

Notes

Burn-in is expected to be performed once modules are installed on rods. The plan would be to burn-in for 3 days. We would have capacity for up to 72 modules on 12 rods. Since this step only requires manpower at the start and finish, we have assigned no technician to this task. The technician doing this work would be from the small group of technicians who have been trained in operation of the test stands. The burn-in would be overseen by the physicists overseeing module and hybrids testing.

8.4.3.6.6 Burn-in (FNAL)

Notes

Burn-in is expected to be performed once modules are installed on rods. The plan would be to burn-in for 3 days. We would have capacity for up to 72 modules on 12 rods. Since this step only requires manpower at the start and finish, we have assigned no technician to this task. The technician doing this work would be from the small group of technicians who have been trained in operation of the test stands. The burn-in would be overseen by the physicists overseeing module and hybrids testing.

8.4.3.6.7 Burn-in (UIC)

Notes

Burn-in is expected to be performed once modules are installed on rods. The plan would be to burn-in for 3 days. We would have capacity for up to 72 modules on 12 rods. Since this step only requires manpower at the start and finish, we have assigned no technician to this task. The technician doing this work would be from the small group of technicians who have been trained in operation of the test stands. The burn-in would be overseen by the physicists overseeing module and hybrids testing.

WBS	Task Name

SiTrk-015 **Rods 25% complete**

Notes

Tracker Level 2 Milestone

SiTrk-016 **Rods 50% complete**

Notes

Tracker Level 3 Milestone

SiTrk-017 **Rods 75% complete**

Notes

Tracker Level 3 Milestone

SiTrk-018 **Rods 100% complete**

Notes

Level 4 Milestone:

This milestone represents the completion of all modules and rods for this project. It marks the end of this project's need for resources at SiDet for module building.

8.4.3.7 Documentation

8.4.3.7.1 Assembly, Test, Ship/receive

Notes

The large numbers and types of components arriving, being stored, and departing from FNAL during this project leads to the need for a substantial documentation and tracking effort. In addition, the numerous tests that are performed on components and completed modules will result in a significant amount of data that will need to be retained. The organization of all of this information requires dedicated support. We foresee the setup of the documentation system being performed in the ramp-up period as described above. In that period a computer professional would be helping us full time. In the production phase, we expect a small group made up of a technician working nearly full time and a physicist contributing 0.25 FTE supported at the 10% FTE level by the computing professional who helped set up the system. The technician dedicated to maintaining the databases will also be responsible for keeping all information up to date. This means all shipments in and out of SiDet are taken into account daily, as are the choice of components used in module production, completed modules, and completed rods. The database is expected to be web-based. Hence, modules sent to UCSB for repair or to other institutions for in-depth quality assurance studies can have information obtained at those sites added to their folders in the database directly from those locations.

8.5 Transportation

Notes

Transportation of completed rods to CERN will be done by courier. I.e. physicists in the group will carry up to 30 rods in a separate economy class seat. These trips to CERN will be chosen to coincide with scheduled trips for collaboration meetings and tracker group meetings.

8.5.1 Shipments to CERN

Notes

The transportation of modules on rods to CERN is still not fully resolved. As mentioned earlier, the transport them as carry on luggage accompanied by a physicist or two physicists.

WBS	Task Name

"Shipments to CERN" continued

Notes

We have conceptual designs for the transportation box which would fit in a coach seat of an airplane. If these boxes could be designed to hold roughly 30, then ~25 box shipments would be required by the end of the project. Assuming that the cost for sending one person to CERN for one week is $2500, then the cost for an additional economy class seat for the modules should not exceed $1500 (mainly the airfare). The cost per box transported to CERN is thus estimated at $4k. For 25 trips, the cost is then 100k$. The contingency is taken to be ~45%.

SiTrk-019 Start Installation of Rods in Wheel

Notes

Tracker Level 2 Milestone

SiTrk-020 Install 50% of Rods in Wheel

Notes

Tracker Level 3 Milestone

SiTrk-021 All Rods Delivered to CERN

Notes

Level 4 Milestone

8.6 Installation and Commissionin

Notes

Once TOB module and rod assembly has been completed in the US, we plan to have physicists and technicians from our group at CERN to participate in the final assembly of the TOB, its installation in the tracker, and the commissionng of the detector.

8.6.1 Final assembly of TOB

Notes

The duration of final assembly is determined by two of the tracker milesones we received from CERN.

1. Start of installation of rods in wheel	1/28/03
2. Delivery of TOB to the tracjer	4/15/04

In this period we assume the following US CMS Tracker group presence at CERN

Physicist	1.0 FTE
Post Doc	1.0 FTE
University Technician	1.0 FTE

We assume 7 round trips to Europe and long-term travel stay allowances for these people.

SiTrk-022 Delivery of TOB to the Tracker

Notes

Tracker Level 2 Milestone

WBS	Task Name
8.6.2	**Installation and Commissioning of th**

Notes

This period include the time from installation of the tracker in the CMS experiment to stable operation of tracker and initial data taking. We have assumed roughly one year.

In this period we assume the following US CMS Tracker group presence at CERN

Physicist	1.5 FTE
Post Doc	1.5 FTE
Student	1.5 FTE

We assume 12 round trips to Europe and long-term travel stay allowances for these people.

8.7 TIB Support Structures

Notes

As discussed above, the US CMS Tracker group has agreed to assist the INFN consortium in preparing support cylinders for the tracker inner barrel (TIB). We would plan to prepare the supports for two of the four layers. The components for these support elements are:
1) C Fiber cylinders which have been made from molded parts and assembled in Italy
2) C Fiber Ribbons
3) High thermal conductivity, precision mounting ledges
4) Pre-formed cooling tubes

In addition to these components, INFN Pisa will provide us with the tooling we need to carry out the assembly. The assembly itself involves
1) the installation and precision alignment of the jigs
2) Installation and placement of the cylinders
3) Placement of all ribbons and cooling tubes
4) Precision placement of the mounting ledges

The latter two steps will take the most time. The 2 layers we are responsible for each entail a complete cylinder which is separated into 4 parts for the assembly of the components mentioned above. The time and manpower we have alloted to this work is based upon the experience of the INFN-Pisa group during the assembly of a prototype cylinder in 1999. We have added significant (56%) manpower contingency.

8.7.1 Equipment

Notes

This task includes the installation of the jigs on CMM's and preparation of all jigs for assembly work to begin.

8.7.1.1 Support Cylinder Gluing Jigs

Notes

The Gluing jigs are of two types as indicated below.

WBS	Task Name

8.7.1.1.1 Ribbon and Cooling Tube Jig

Notes

This jig is used for the installation of the cooling pipes and also for the installation of the Carbon fiber ribbons that are used to support the precision, thermally conductive mounting ledges. Note that the Tracker Inner Barrel (TIB) does not use rods as is true for the TOB. Instead, modules are mounted individually to the cylinder supports using the precision mounting ledges. This is a technique that was used for the construction of the CDF ISL detector.

8.7.1.1.1.1 Install Jigs at SiDet and Prepare for U

Notes

The task of installing and preparing the Ribbon and cooling tube jigs will be done mainly by visiting INFN-Pisa technicians. We anticipate 1 FTE FNAL technician support and involvement. The FNAL technician involved in the setup will later be the person responsible for using the jig.

8.7.1.1.2 Precision ledge placement jig

Notes

This jig is used for the installation of the precision, thermally conductive mounting ledges. Note that the Tracker Inner Barrel (TIB) does not use rods as is true for the TOB. Instead, modules are mounted individually to the cylinder supports using the precision mounting ledges. This is a technique that was used for the construction of the CDF ISL detector.

8.7.1.1.2.1 Install Jig at SiDet and Prepare for Us

Notes

The task of installing and preparing the ledge placement jig will be done mainly by visiting INFN-Pisa technicians. We anticipate 1 FTE FNAL technician support and involvement. The FNAL technician involved in the setup will later be the person responsible for using the jig.

8.7.2 Assembly

Notes

This task covers the actual assembly of the TIB barrel supports.

8.7.2.1 Attachment of cooling tubes and ribb

Notes

We have assigned a substantial labor force to the installation of the cooling tubes and ribbons on the support cylinders. In particular we plan to have 1.5 FTE technicians and 0.25 FTE Tech. Specialist involved in this work. This will enable us to both install and survey the cooling tubes and ribbons accurately with good oversight by a higher level technician.

8.7.2.2 Attachment of precision positioning l

Notes

We have assigned a substantial labor force to the installation of the precision mounting ledges on the support cylinders. In particular we plan to have 1.5 FTE technicians and 0.25 FTE Tech. Specialist involved in this work. This will enable us to both install and survey the cooling tubes and ribbons accurately with good oversight by a higher level technician.

WBS	Task Name
8.7.3	**Shipment**

Notes

Assembled support cylinders will be shipped to Pisa, where modules will be installed before shipment to CERN. The shipments are estimated to cost no more than $1500 each for the 8 quadrants we will construct. Unlike the rods that we will ship to CERN, these pieces can be shipped cargo. The price quoted is believed to be adequate to cover the air freight and the packaging. The packages will be fairly small (of order 60 cm x 50 cm x 30 cm).

8.7.3.1 Ship completed support structures to

Notes

The transport of the quadrants of the support cylinders may take place as they are finished or all at once when they are all complete. Most likely the former will be true. In any case, this has no relevance for the cost, since we are assuming $1.5k for each quadrant. We plan to have all parts returned to Pisa by early 2003. This will minimize conflict with CDF and D0 Run 2b projects over CMM usage.

SiTrk-023 All Supports Completed and Shipped

Notes

US CMS Level 2 Milestone

SiTrk-024 Tracker Detector Installed